Modeling Conflicts of Multiple Independent Alerting Systems

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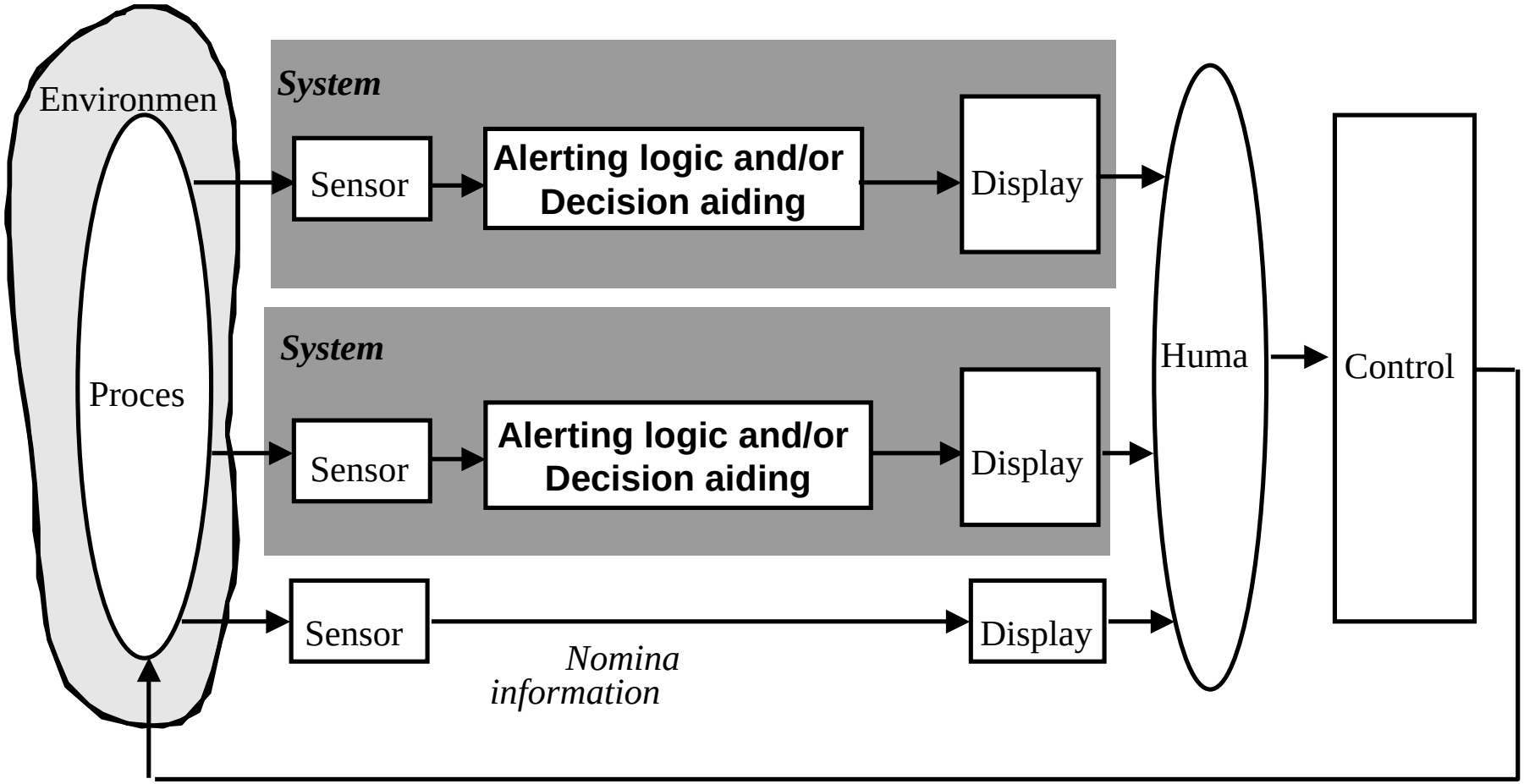
Why Implement Multiple Alerting Systems

- Existing systems intended for specific roles, new alerting have been introduced to provide additional protection in new applications (TCAS/AILS)
- Different timescales

  GPWS vs. EGPWS

  TCAS vs. ATC conflict probe
- Due to cost and certification issues, the new systems have been introduced independently rather than modifying and enhancing existing system (GPWS/EGPWS)

Multiple Alerting Systems



Conflict

- **Dissonance between human and automation**
  - Difference between an alerting system's decision and a human internal model of a threat situation
    - Pritchett and Hansman explored the concepts
- **Dissonance between two or more alerting systems**
  - Each system uses different set of sensors
  - Different logic for
    - Alert stage
    - Resolution guidance
  - Different displays

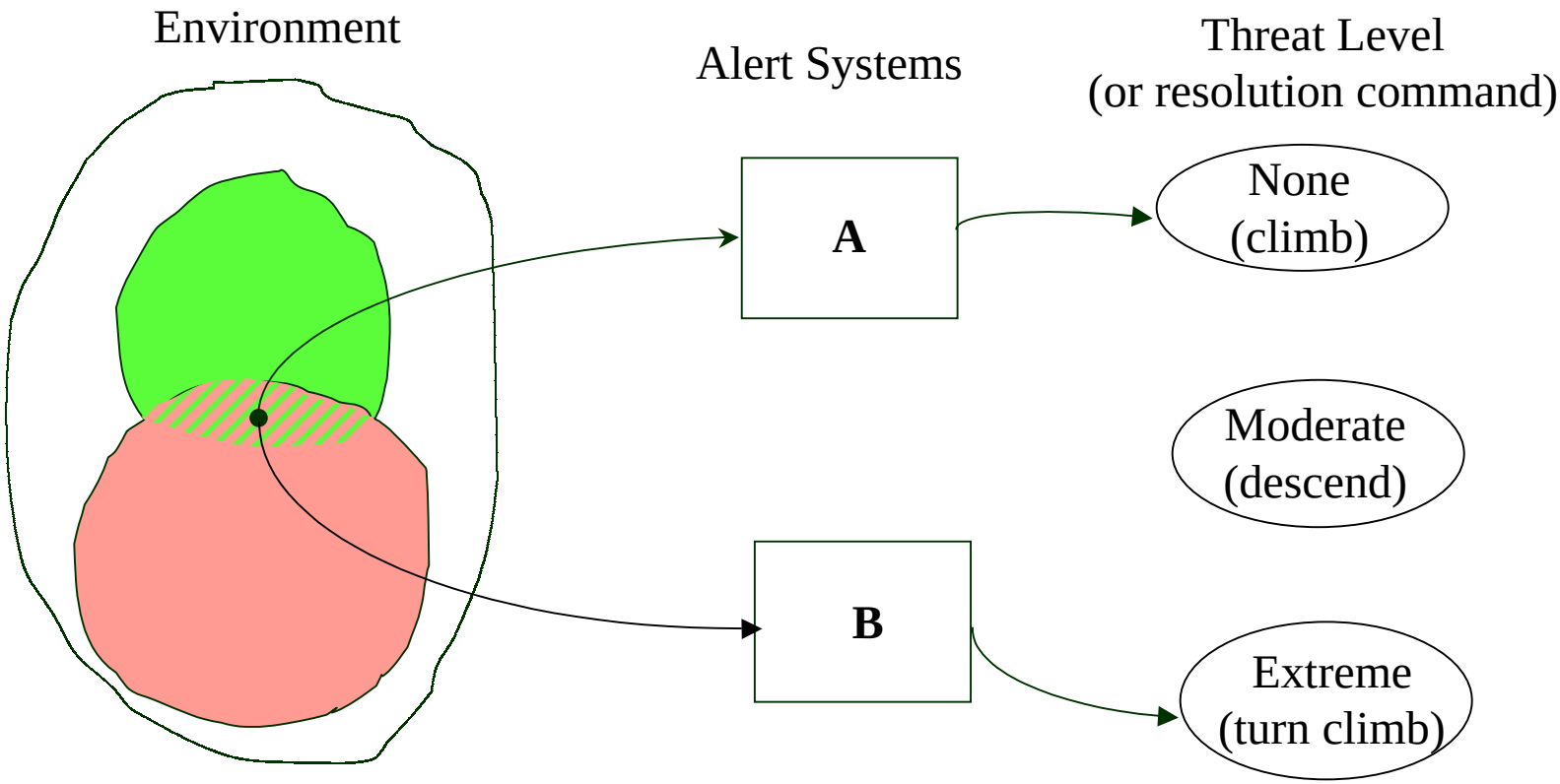
Undesirable Effects of

- **Human vs. Automation**
  - ❑ Increased delay in taking action
  - ❑ Failure to take action at all
  - ❑ Implementing an action contrary to the automation command
- **Automation vs. Automation**
  - ❑ Same as above
  - ❑ Overloading or confusing the human
- **Long-term**
  - ❑ Distrust of automation in the future

Methods to Mitigate Alert Conflicts

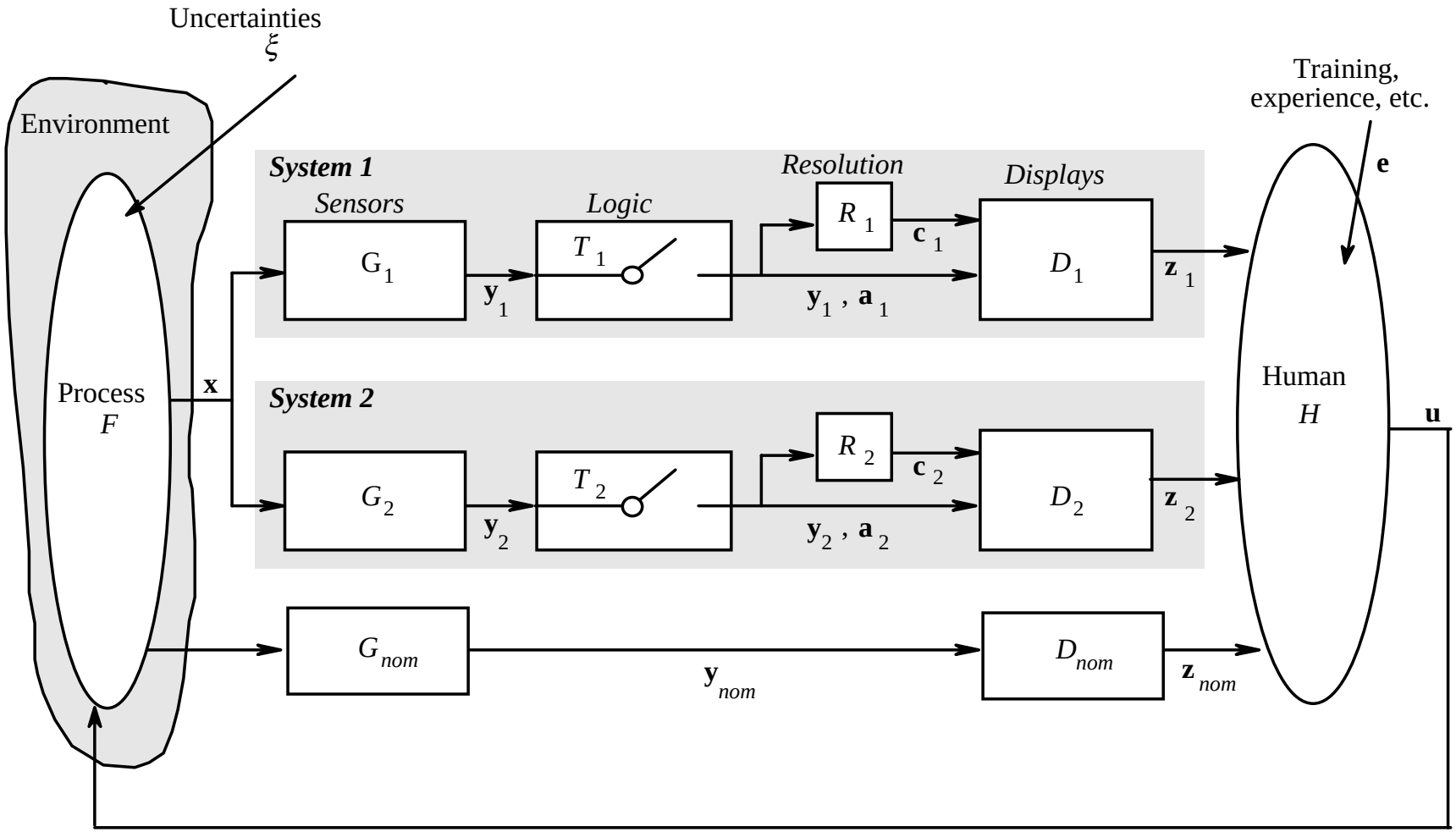
- **To date, the conflict issue has been largely managed through prioritization**
  - ❑ Inhibit one of the alerts
  - ❑ Problem when both alerts are valid
- **Procedurally prevent conflict (aircraft flight path restriction)**
  - ❑ Modify air traffic control procedures to reduce the likelihood of a simultaneous TCAS alert and parallel traffic alert
- **Training the pilot**
  - ❑ Training may fall short (two accidents of Boeing B757 aircraft in 1996)
- **Modify system design to reduce impact/frequency of conflicts**
  - ❑ Need a more formal method to identify the potential of dissonance and develop the mitigation method

High Level Overview of Types



Dissonance may occur whenever a given state maps into two different alert stages or two different resolution commands or when the time-derivatives of these mappings differ

State-space Model for Multiple Alerting Systems



Alerting Systems Conflict Types

Static Conflict and Dynamic Conflict

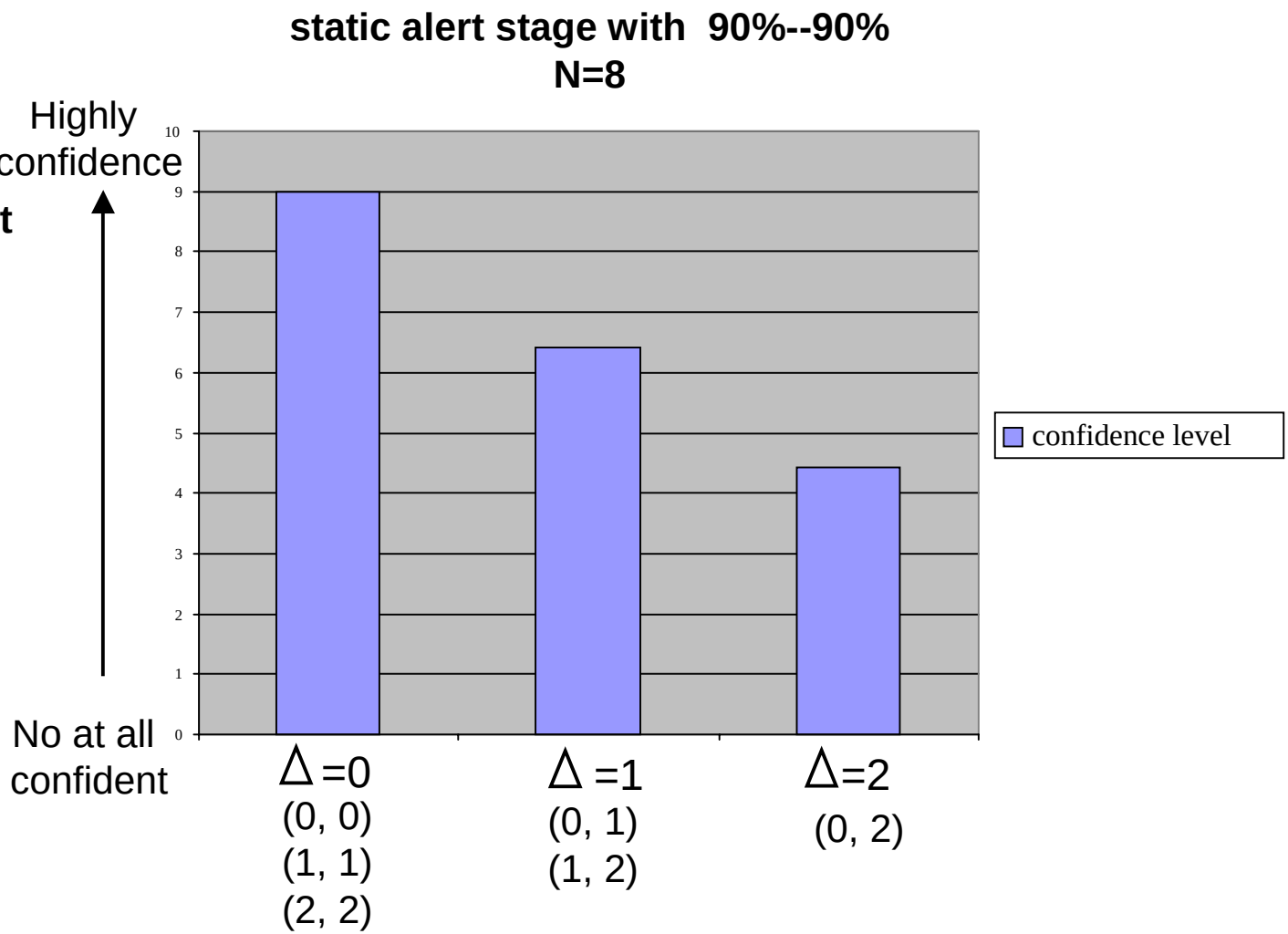
Information Element		Example Dissonance	
		System 1	*System 2*
Alert Stage	system alert stage	no threat	warning
	hazard alert stage	aircraft A is a threat	aircraft B is a threat
Resolution	dimension	turn	climb
	polarity	climb	descend
	magnitude	turn 5Þ	turn 30Þ

Human Factor Issues

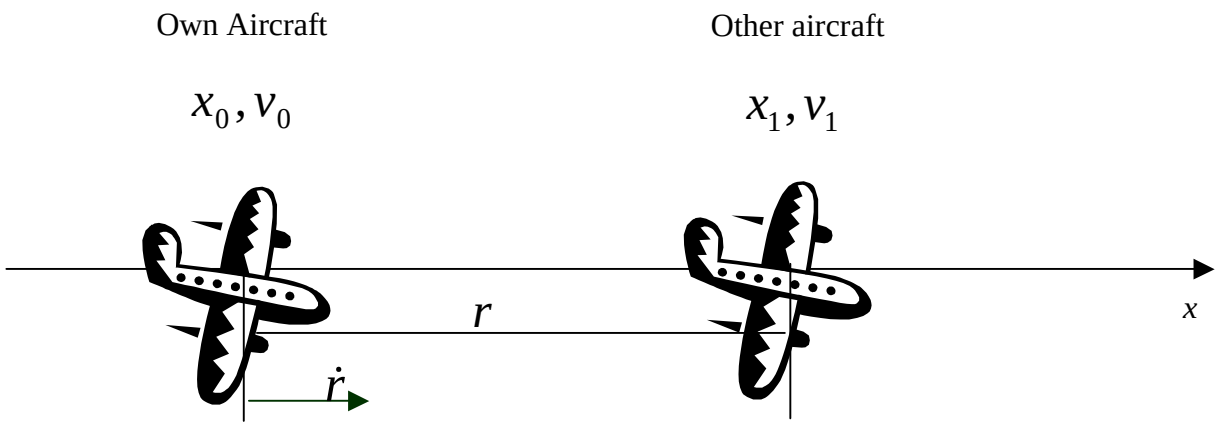
- **Work to date has focused on mathematical identification of information from each system disagrees. Also critical is determining:**
  - ❑ How much difference between the information provided to the human operator may result in dissonance
  - ❑ How rapidly systems must change for dynamic dissonance to occur
  - ❑ Human operator's internal model of the threat situation

Preliminary Human Factor Study

- **Difference are statistically significant ($p<0.05$)**
- **Also investigating dynamic effects**



One-Dimensional Example(1)

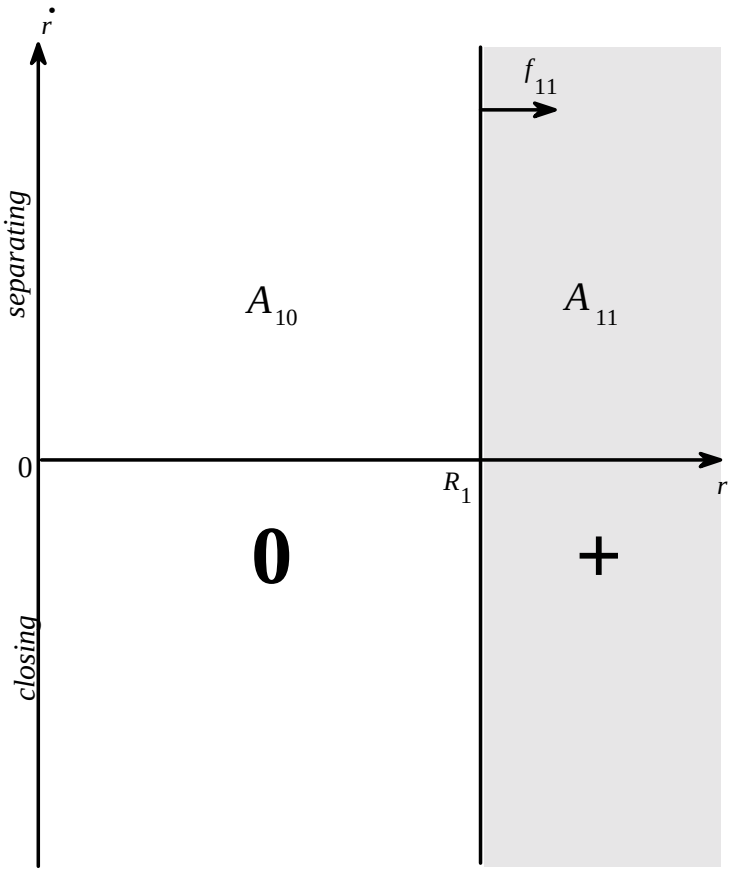


Own Aircraft(trail) has two systems:

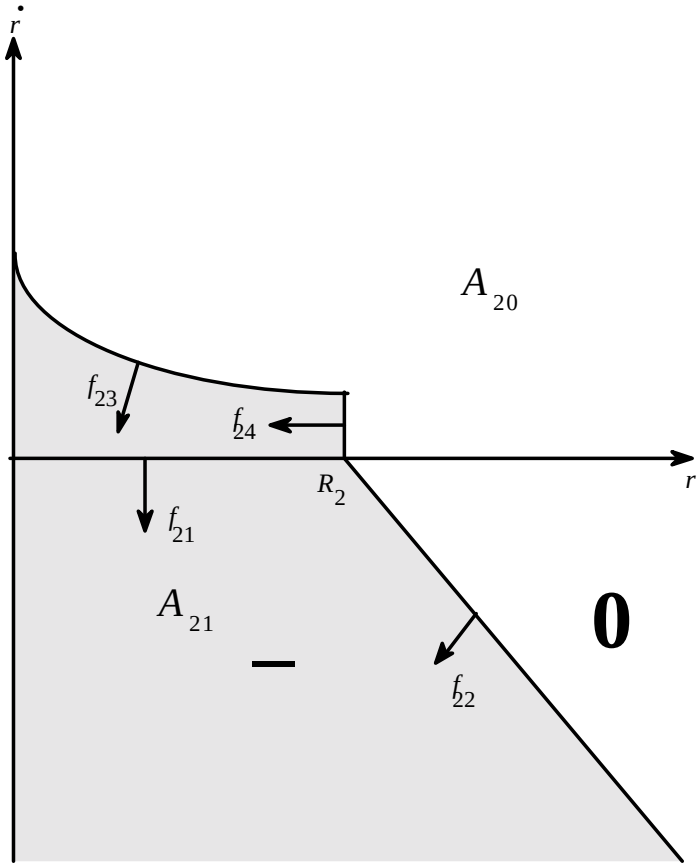
System 1: Simple proximity logic: command accelerate if range > threshold (r)

System 2: TCAS-like logic:command decelerate if time to impact < threshold $(r, \dot{r})$

One-Dimensional Example(2) ---system logic

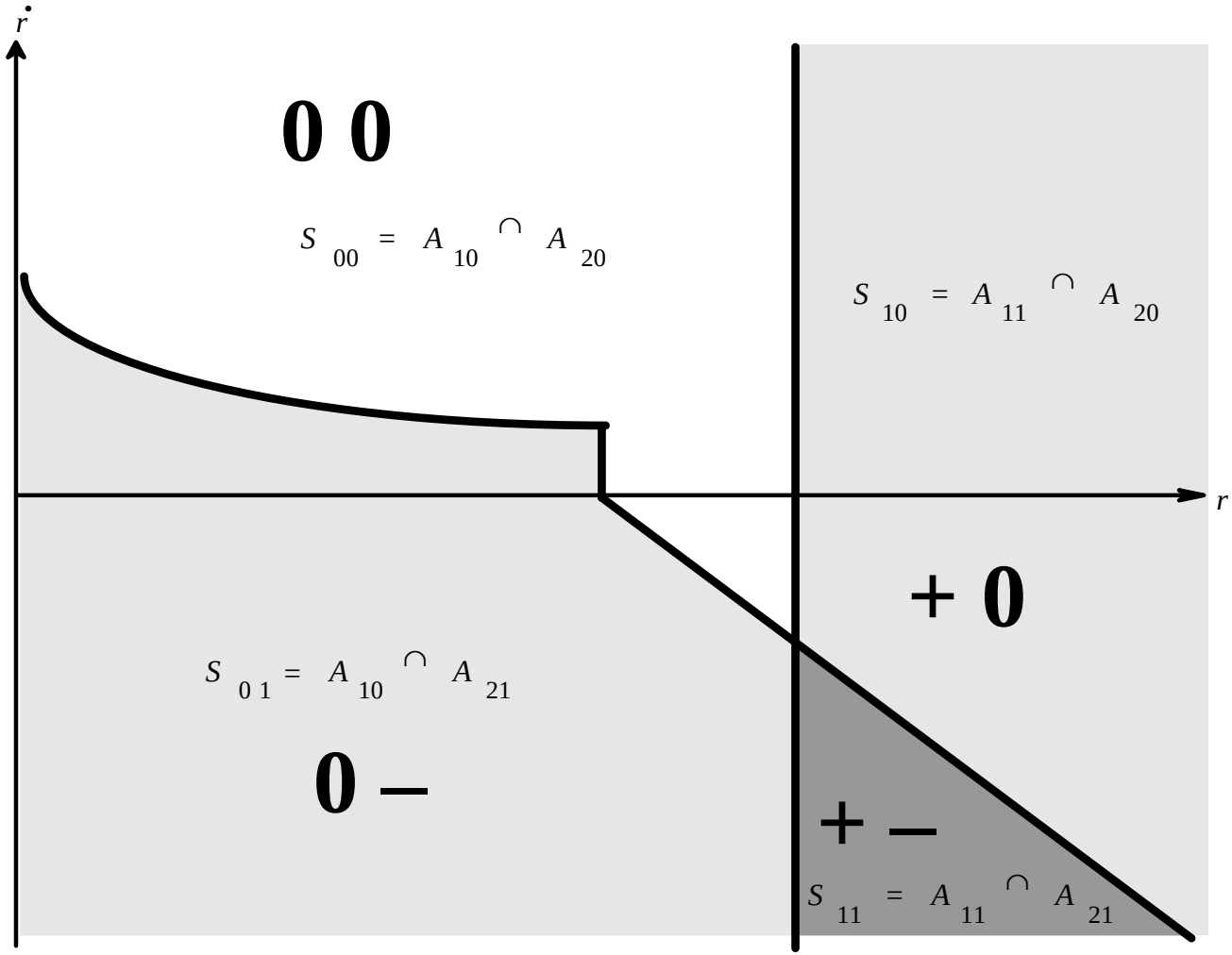


System 1

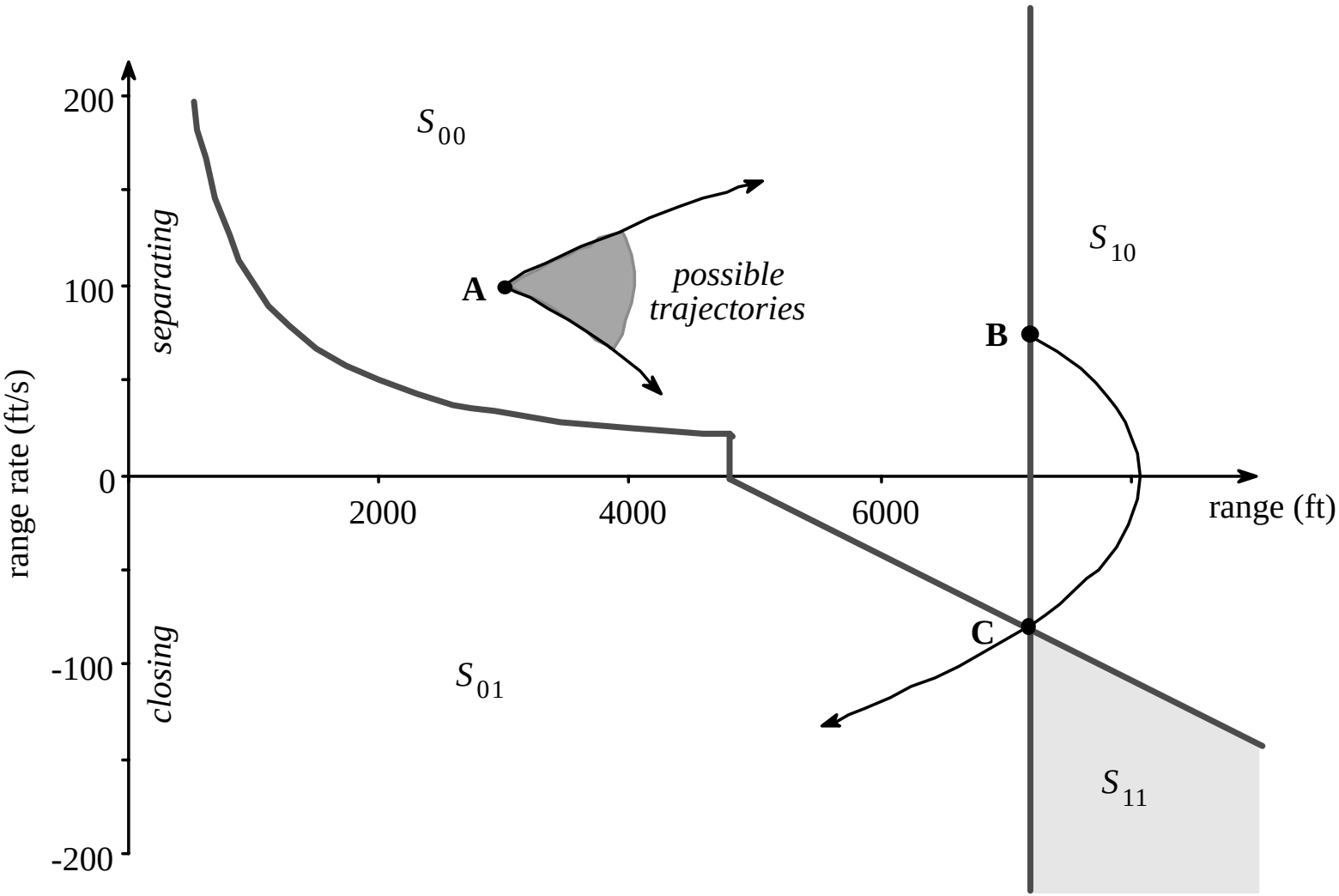


System 2

One-Dimensional Example(3) ----static conflict conditions



One-Dimensional Example(4) ----possible dynamic conflict



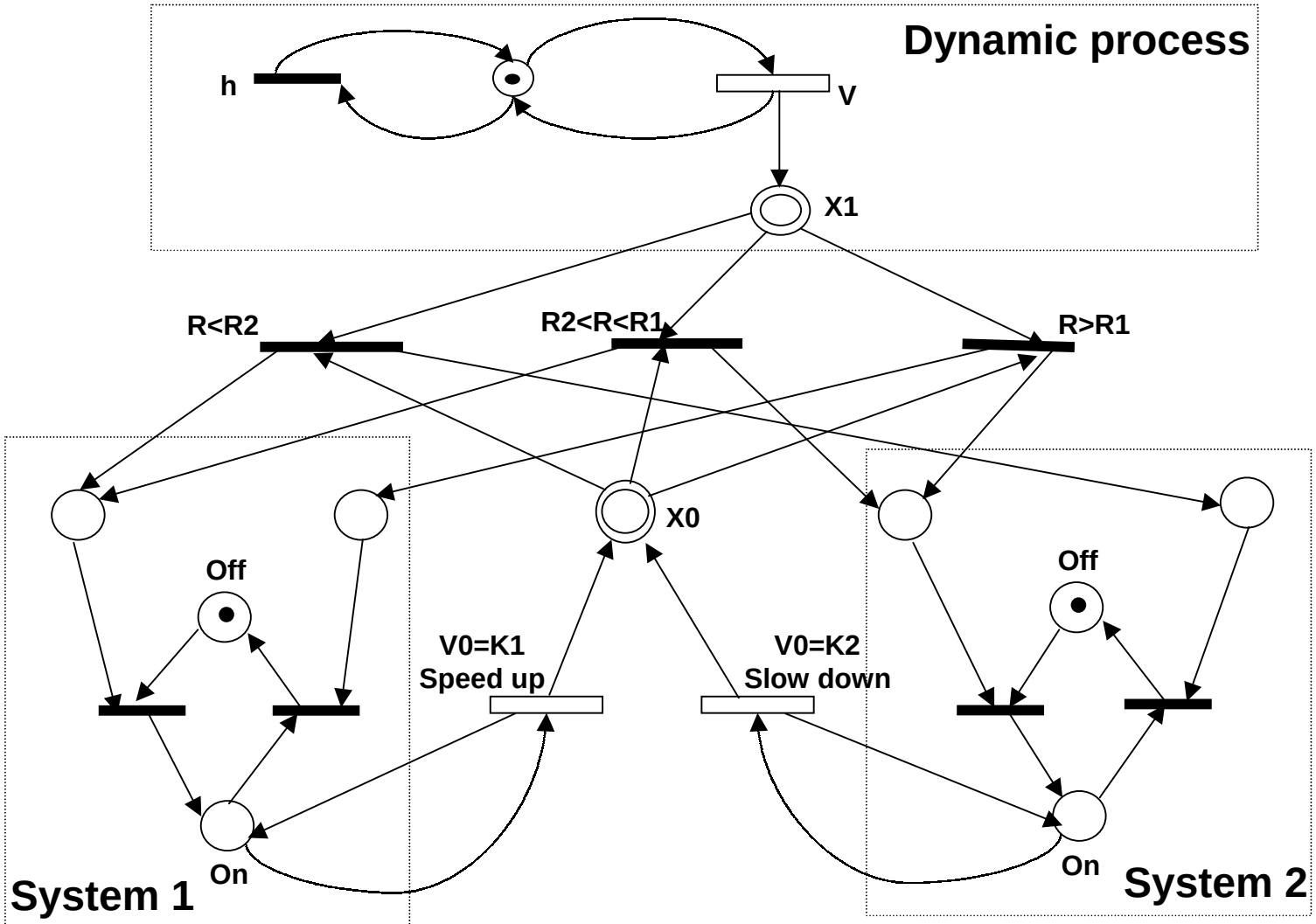
Restrictions on the Model

- **Hard to describe and analyze complicated logic**
  - ❑ Assumes/Requires functional relationship between states and alert
- **Hard to present results and describe behavior**
  - ❑ Multidimensional case
  - ❑ Identification of conflict sets depends on human factors issues

Petri Nets
---A Formal Method

- **To express the system logic**
  - ❑ Capture temporal behavior
  - ❑ Better represents modes/stages
- **To find the conflict conditions between system logic**
- **To find controls to avoid dynamic conflict**
- **To avoid situations leading to dynamic conflict**

An Example of Multiple Alerting Systems Model Using Petri Net



Concept of Safety in Petri Nets

- A process is “unsafe” when it reaches certain undesired states
- The safety verification problem is determining whether a sequence of control may lead the system from any initial condition to any potentially unsafe condition within certain time
- For multiple alerting systems, use petri net to find situations leading to conflict and design optimal control to avoid entering the conflict region within certain time
- Plan to apply PNs to example aviation problem(e.g. TCAS & Airborne Conflict Management)